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GB 2234611 A **WO 93/10498 A1** **US 5432950 A**
US 5379212 A **US 4698750 A** **US 4590552 A**

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UK CL (Edition P) **G4A AAP, H4L LDSK LECC**
INT CL[6] **G06F 12/14, H04Q 7/32 7/38**
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(54) Abstract Title
Securing electronic information in a wireless communication device

(57) A wireless communication device such as a portable cellular telephone has a microcontroller 202 and an external memory 204. The microcontroller has a one-time - programmable security flag 230 that is programmed when electronic information such as an ESN (electronic serial number) is stored in the memory. Once programmed, the security flag prevents reprogramming of the memory with a different or 'cloned' ESN. The microcontroller also comprises an algorithm that generates electronic authentication information 207 from the electronic information. The authentication information is also stored in the memory. Upon retrieval from the memory for registration, the electronic information is authenticated by generating new authentication information to compare with the authentication information previously stored. The security and authentication of electronic information may be applied to any program stored in a ROM external to a microcontroller.

FIG.2 200

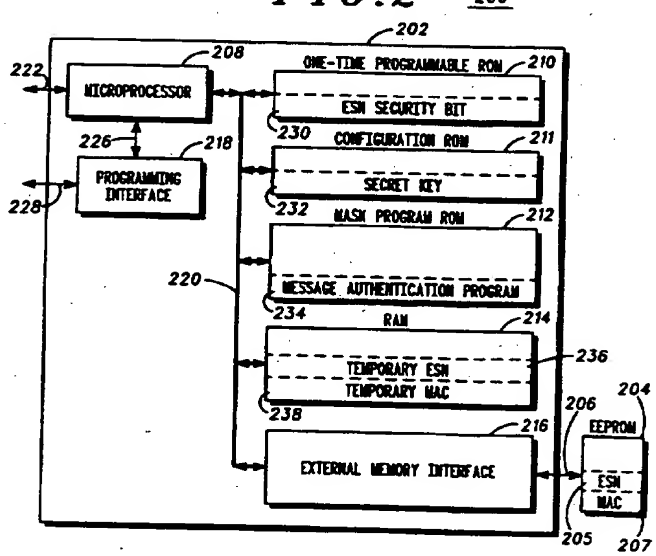

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FIG.1 100

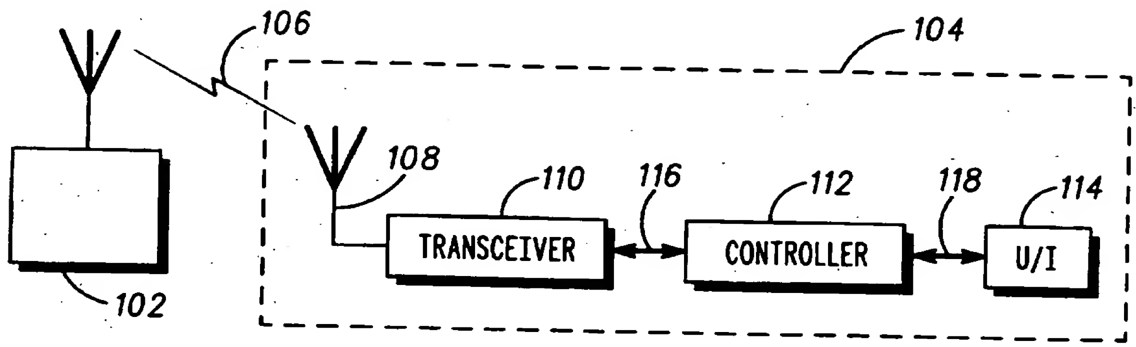


FIG.2 200

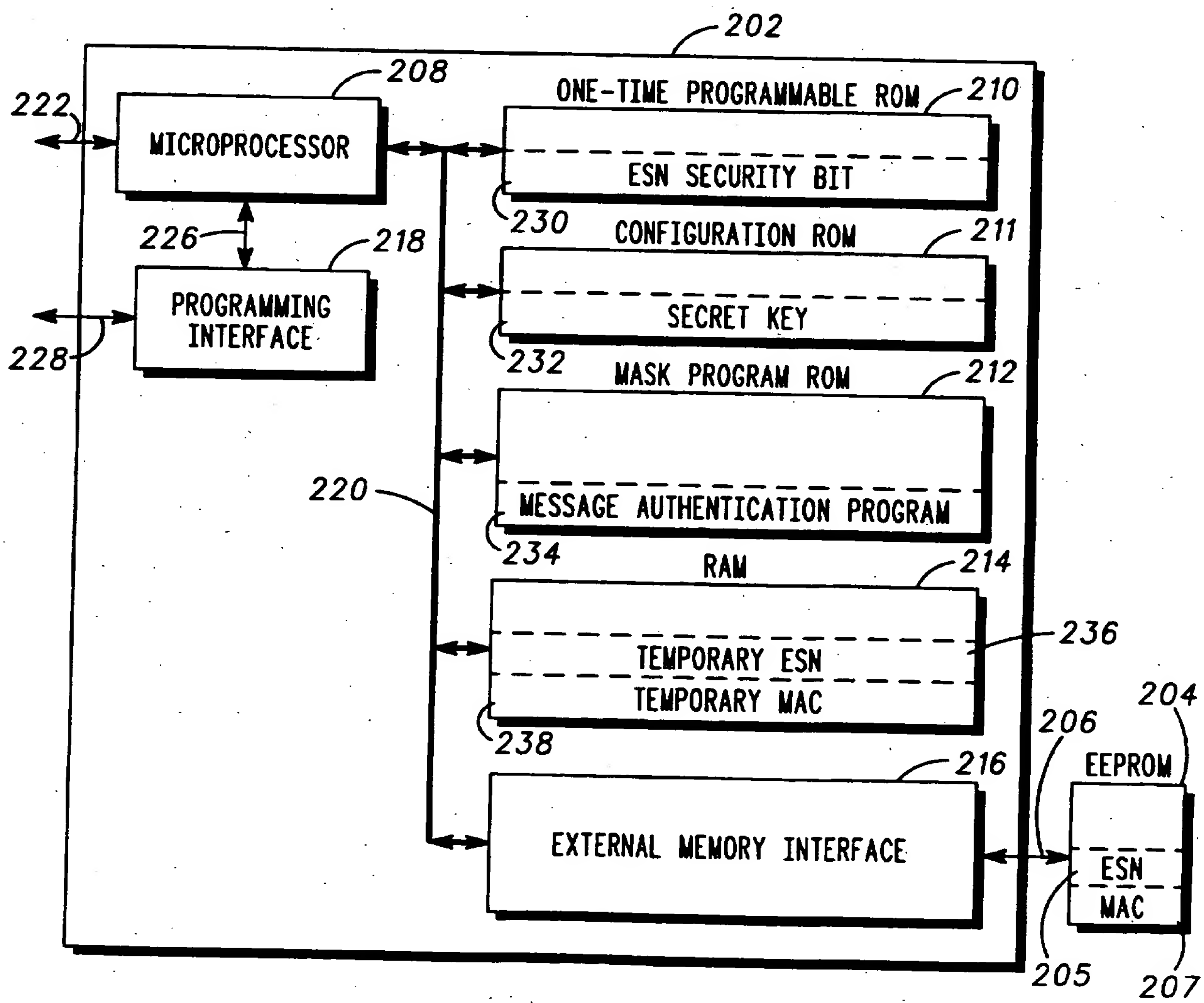


FIG. 3

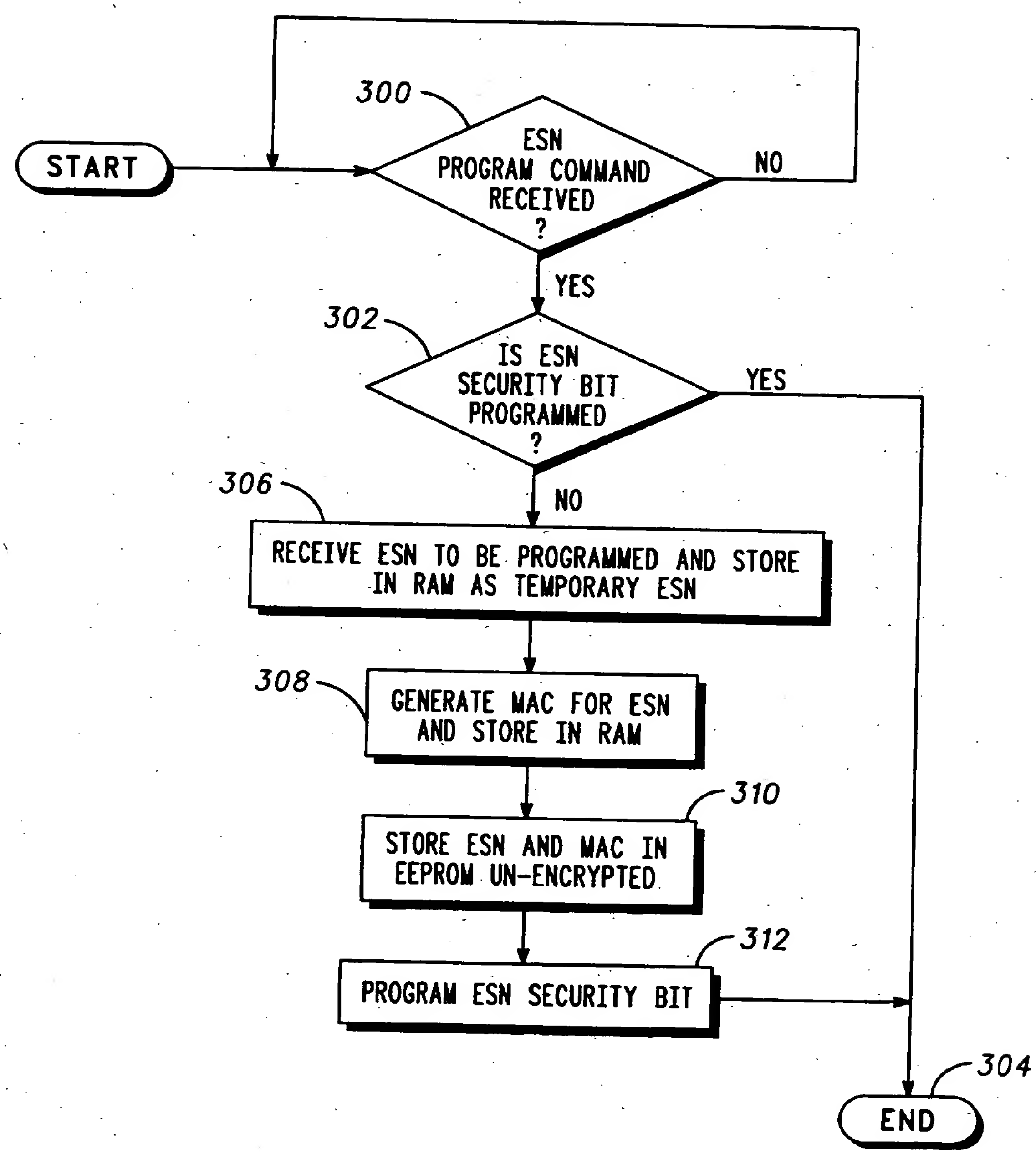

START
300
ESN PROGRAM COMMAND RECEIVED ?
NO
YES
302
IS ESN SECURITY BIT PROGRAMMED ?
YES
306
NO
RECEIVE ESN TO BE PROGRAMMED AND STORE IN RAM AS TEMPORARY ESN
308
GENERATE MAC FOR ESN AND STORE IN RAM
310
STORE ESN AND MAC IN EEPROM UN-ENCRYPTED
312
PROGRAM ESN SECURITY BIT
304
END

FIG. 4

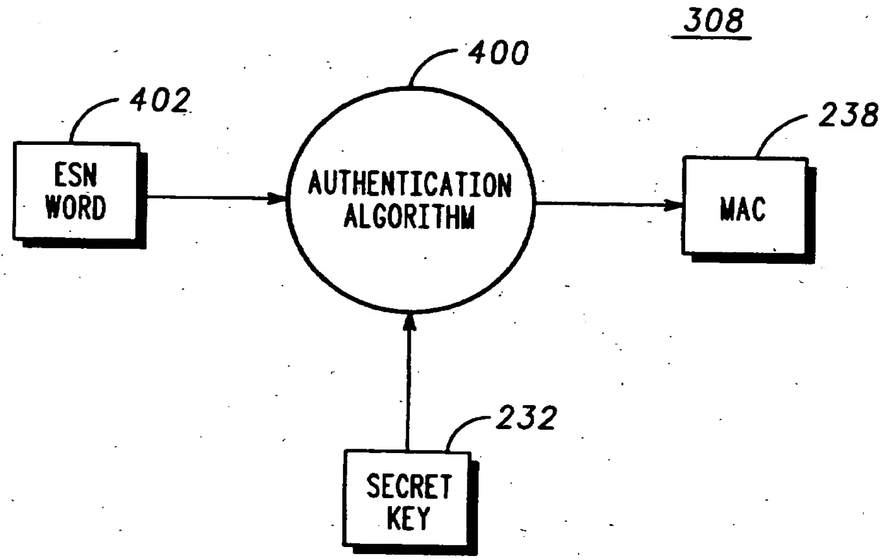
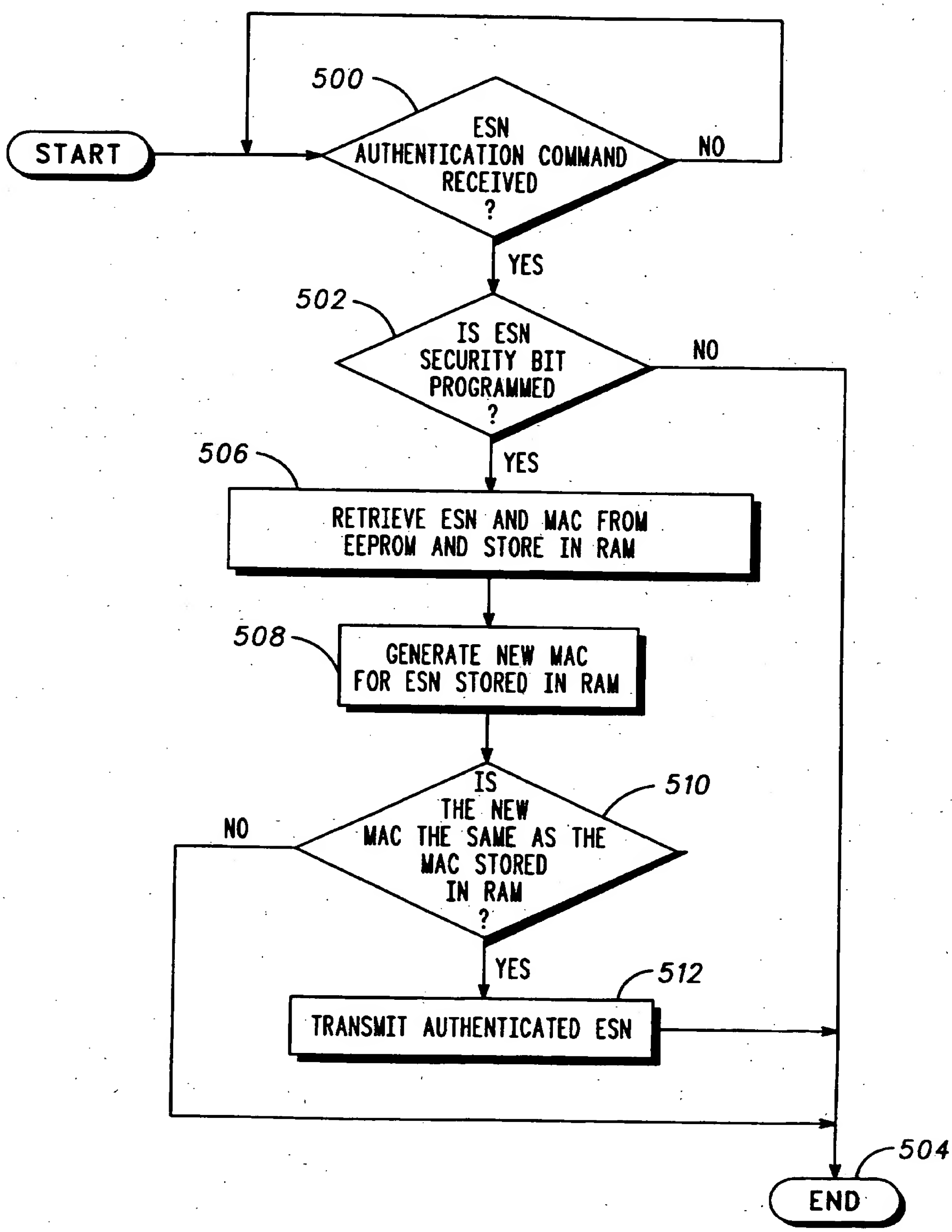

308
400
402
238
ESN WORD
AUTHENTICATION ALGORITHM
MAC
232
SECRET KEY

FIG. 5


START
500
ESN AUTHENTICATION COMMAND RECEIVED ?
NO
YES
502
IS ESN SECURITY BIT PROGRAMMED ?
NO
YES
506
RETRIEVE ESN AND MAC FROM EEPROM AND STORE IN RAM
508
GENERATE NEW MAC FOR ESN STORED IN RAM
510
IS THE NEW MAC THE SAME AS THE MAC STORED IN RAM ?
NO
YES
512
TRANSMIT AUTHENTICATED ESN
504
END

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APPARATUS AND METHOD FOR SECURING ELECTRONIC INFORMATION IN A WIRELESS COMMUNICATION DEVICE

Field of the Invention

The present invention relates generally to a wireless communication device and more particularly to electronic information stored in a wireless communication device.

Background of the Invention

Wireless communication systems have become increasingly common. In such systems, a subscriber uses a local communication device, such as a portable cellular telephone, to communicate with a remote communication device, such as a cellular base station. Communication is accomplished via the transmission of radio frequency (RF) signals between the local device and the remote device.

To initiate communication, the local device communicates electronic information, such as an electronic serial number (ESN), to the remote device for registration. Upon receipt, the remote device determines whether the local device is permitted to make calls in the system based on the ESN. Aside from being used for limiting system access only to authorized users, the ESN is used for billing subscribers for calls made over the system.

In many wireless communication systems, the ESN is transmitted to the remote device in an un-encrypted manner and, thus, it is not secret and is susceptible to receipt by an unauthorized party. The unauthorized party may engage in fraudulent activity by programming the electronic information into, and making counterfeit calls via, a local device. Such fraud results in billing authorized subscribers for calls they did not make.

In the past, the risk of fraud was reduced by storing the ESN in a non-volatile memory device within a semiconductor device, such as

an integrated circuit. More specifically, the ESN was stored in an EEPROM (electrically erasable programmable read only memory) that was internally disposed in a microcontroller employed by the local communication device. In operation, the EEPROM could not be accessed via the pinouts of the microprocessor and, thus, could not easily be reprogrammed or replaced with a "cloned" ESN.

However, combining an EEPROM on the same integrated circuit as a microcontroller is very expensive. The semiconductor manufacturing processes capable of providing non-volatile memory devices are expensive relative to those processes capable of providing logic circuitry only. Also, where the non-volatile memory and the logic circuitry are combined in a single microcontroller, yield reductions due to non-volatile memory programming failures can greatly increase the expense of the finished product.

Therefore, what is needed is an apparatus and method for securing electronic information, such as an ESN, that does not require the use of a non-volatile memory device packaged within a microcontroller device.

Brief Description of the Drawings

FIG. 1 is a block diagram illustrating a wireless communication system employing remote and local communication devices;

FIG. 2 is a block diagram of an apparatus employed in a controller of the local communication device of FIG. 1;

FIG. 3 is a flowchart illustrating a method employed by the apparatus of FIG. 2 for programming electronic information therein;

FIG. 4 is a functional block diagram illustrating a method employed by the apparatus of FIG. 2 for generating an authentication code associated with the electronic information of FIG. 3; and

FIG. 5 is a flowchart illustrating a method employed by the apparatus of FIG. 2 to authenticate the electronic information of FIG. 3.

Detailed Description of the Preferred Embodiments

An apparatus for securing electronic information includes a non-volatile memory and a microcontroller. The memory is externally coupled to the microcontroller. The microcontroller comprises a one-time programmable security flag that is programmed when the electronic information is stored in the memory. Once programmed, the security flag prevents reprogramming of the memory. Additionally, the microcontroller comprises an encryption algorithm that generates electronic authentication information during programming of the electronic information. The electronic authentication information is stored in the memory along with the electronic information. Upon retrieval from the memory for registration, the electronic information is authenticated by generating new electronic authentication information via the encryption algorithm to compare to the electronic authentication information stored in the memory. Such authentication prevents swapping out of the memory to gain system access. Thus, unlike the previous apparatuses, the present apparatus secures electronic information in a memory external to a microcontroller.

A communication system 100, shown in FIG. 1, comprises remote and local communication devices 102 and 104 that communicate via a wireless communication link 106. In the illustrated embodiment, the remote and local devices 102 and 104 are a cellular base station and a cellular radiotelephone, respectively, and the wireless link 106 comprises RF signals. The local device 104 includes an antenna 108, a transceiver 110, a controller 112, and a user interface 114. The user-interface 114 typically includes a microphone, a speaker, a keypad, a display, and an external test connector.

When the local device 104 is in a powered-on state, the RF signals of the wireless link 106 are received by the antenna 108 and converted by the transceiver into receive data signals, which are coupled to the controller 112 via bus 116. The controller 112 processes the received data and voice signals that are further coupled, via bus 118, to the user interface 114 for output. Voice and data input to the user

interface 114 is coupled to the controller 112, via bus 118, for processing into transmit data signals. The controller 112 outputs the transmit signals on bus 116 for conversion by the transceiver 110 and emission by the antenna 108 as the RF signals of the wireless link 106.

The controller 112 includes an apparatus 200, shown in FIG. 2. The apparatus 200 includes a microcontroller 202 and an EEPROM 204. The EEPROM 204 interfaces to the microcontroller 202 via a serial format. The EEPROM 204 includes a location for storing electronic information. In the illustrated embodiment, the electronic information is an electronic serial number (ESN) 205 consisting of a 32 binary bit number. The ESN 205 uniquely identifies the local device 104 of FIG. 1 and is used by the local device 104 of FIG. 1 to gain authorized access to the communication system 100. The EEPROM 204 of FIG. 2 also includes a location for storing electronic authentication information used to authenticate the electronic information. In the illustrated embodiment, the electronic authentication information is a message authentication code (MAC) 207 consisting of a 32 binary bit number.

The microcontroller 202 comprises a microprocessor 208, a one - time programmable ROM (read-only memory) 210, a configuration ROM 211, a mask program ROM 212, a RAM (random-access memory) 214, an external memory interface 216, and a programming interface 218. The microprocessor 208 is coupled to the programming interface 218 via serial bus 226, which is internal to the microcontroller 202. The microprocessor 208, the one-time programmable ROM 210, the configuration ROM 211, the mask program ROM 212, the RAM 214, and the external memory interface 216 are coupled by a common parallel bus 220, which is internal to the microcontroller 202. The microprocessor 208 is coupled to the transceiver 110, other circuitry of the controller 112, and the user interface 114 via bus 222, which extends outside of the microcontroller 202. The programming interface 218 is coupled to the user interface 114 via bus 228, which extends outside of the microcontroller 202. Busses 222 and 228 may form sub-busses of busses 116 and 118 of FIG. 1. The external memory interface 216 of FIG. 2 is coupled to the EEPROM 204 via bus 206, which extends outside of

the microcontroller 202. The microcontroller 202 is preferably fabricated in a single integrated circuit using known semiconductor fabrication techniques.

The microprocessor 208 is a parallel device that operates responsive to program instructions and data for controlling the apparatus 200. The program instructions are electronic information stored in the mask program ROM 212 or a ROM (not shown) externally coupled to the microcontroller 202. The data is electronic information preferably stored in the configuration ROM 211 and the RAM 214. Via the common bus 220, the microprocessor 208 accesses the one-time programmable ROM 210, the configuration ROM 211, the mask program ROM 212, and the RAM 214 to retrieve electronic information, such as the program instructions and data, therefrom; to execute program instructions therein; to store electronic information therein; and the like. All bus transactions involving the common bus 220 are not visible outside of the microcontroller 202. The one-time programmable ROM 210, the mask program ROM 212, and the RAM 214 can not accessed outside of the microcontroller 202.

The one-time programmable ROM 210 includes a location for storing a security flag for preventing reprogramming of the electronic information. In the illustrated embodiment, the security flag is an ESN security bit 230 consisting of a one binary bit number. A binary "one" in the ESN security bit 230 indicates that the ESN 205 and MAC 207 have been programmed into the EEPROM 204. A binary "zero" in the ESN security bit 230 indicates that the ESN 205 and the MAC 207 have not been programmed into the EEPROM 204. The ESN security bit 230 is stored in the one-time programmable ROM 210 during programming of the electronic information, as further described below. The one-time programmable ROM 210 may be implemented by a fuse bank or other one time programmable technology.

The configuration ROM 211 includes a location for storing an encryption key used in the generation of the electronic authentication information. In the illustrated embodiment, the encryption key is a secret key 232 consisting of 64 binary bits that comprise a random 56 binary bit number and an 8 binary bit checksum. The secret key 232 is

stored in the configuration ROM 211 during fabrication of the microcontroller 202, such as at wafer probe using laser trim or fusible link techniques. To ensure security of the secret key 232, the microcontroller 202 disables accesses to the secret key 232 while executing code external to the mask program ROM 212. Such security measures are further described in U.S. Patent Application Ser. No. 08/730,188, "Microcontroller Which Limits Access to Internal Memory", filed in behalf of Dorsey et al. on October 14, 1996, and assigned to Motorola, Inc.

The mask program ROM 212 includes a location for storing instructions for authenticating the electronic information. In the illustrated embodiment, the instructions are a message authentication program 234. The message authentication program 234 is preferably stored in the mask program ROM 212 during fabrication of the microcontroller 202.

The RAM 214 provides locations for temporary storage of the electronic information and the electronic authentication information during programming and authentication processes described further below. In the illustrated embodiment, the electronic information is temporarily stored in the RAM 214 as a temporary ESN 236 comprising a 32 binary bit number and the electronic authentication information is temporarily stored in the RAM 214 as a temporary MAC 238 comprising a 32 binary bit number.

The external memory interface 216 provides compatibility between the microprocessor 208 and the EEPROM 204. The external memory interface 216 converts electronic information output by the microprocessor 208 from a parallel format on bus 220 into a serial format on bus 206. Likewise, the external memory interface 216 converts electronic information retrieved from the EEPROM 204 via bus 206 from a serial format into a parallel format on bus 220.

The programming interface 218 permits programming of the electronic information into the apparatus 200. The programming interface 218 provides compatibility between the microprocessor 208 and an external programming fixture (not shown) that detachably couples to the external test connector of the user interface 114. In the

illustrated embodiment, the programming interface 218 converts the electronic information output by the external programming fixture from a proprietary protocol, such as the three-wire bus protocol or the DSC (Digital Speech Control) protocol, on bus 228 into a serial format on bus 226. Likewise, the programming interface 218 converts electronic information output by the microprocessor 208 from a serial format on bus 226 into the proprietary protocol on bus 228.

The electronic information is programmed into the apparatus 200 according to a method illustrated in FIG. 3. The method of FIG. 3 is described hereinbelow in conjunction with FIG. 2. The method is performed by the microprocessor 208 as part of its program instructions. The method is initiated upon attachment of the programming fixture to the programming interface 218 (via the user interface 114 and bus 228) and reception of an ESN program command from the programming fixture (at block 300). Upon reception of the command, the microprocessor 208 reads the ESN security bit 230 from the one-time programmable ROM 210 (at block 302). If the ESN security bit 230 is a binary "one" (i.e., the ESN security bit 230 has already been programmed), the microprocessor 208 responds to the ESN program command by halting this subsequent attempt to program an ESN into the EEPROM 204 (at block 304).

If the ESN security bit 230 is a binary "zero", the microprocessor 208 proceeds to program the EEPROM 204. The microprocessor 208 responds to the ESN program command by receiving an ESN from the programming fixture and temporarily storing this ESN in the RAM 214 as the temporary ESN 236 (at block 306). The microprocessor 208 generates a MAC associated with the temporary ESN 236 and stores this MAC in the RAM 214 as the temporary MAC 238 (at block 308).

The temporary MAC 238 is generated according to a method illustrated in FIG. 4. The method is embodied in the message authentication program 234 of FIG. 2 stored in the mask program ROM 212. The message authentication program 234 is executed from the mask program ROM 212 by the microprocessor 208. The message authentication program 234 comprises an authentication algorithm 400 of FIG. 4. The authentication algorithm 400 is an encryption algorithm

that generates electronic authentication information from electronic information using an encryption key.

In the illustrated embodiment, the authentication algorithm 400 is the Data Authentication Algorithm (DAA) defined by the National Institute of Standards of the U.S. Department of Commerce in FIPS (Federal Information Processing Standards) Publication No. 113. The DAA uses the Data Encryption Standard (DES) defined by the National Institute of Standards of the U.S. Department of Commerce in FIPS Publication No. 46-1. To generate the temporary MAC 238, the microprocessor 208 retrieves the secret key 232 from the configuration ROM 211 and inputs the secret key 232 and an ESN word 402 to the authentication algorithm 400.

For compatibility with the DES, the ESN word 402 comprises a 64 bit binary number or a multiple of a 64 bit binary number. In one embodiment, the microprocessor 208 generates the ESN word 402 by appending 32 binary "zero" bits to the end of the temporary ESN 236. In another embodiment, the microprocessor 208 appends a message, such as a hash code, to the end of the temporary ESN 236. A hash code is a condensed representation of a larger message. One example of the hash code would be a 32 binary bit check sum generated from the contents of the mask program ROM 212. Another example would be a message digest generated in accordance with the Secure Hash Algorithm (SHA-1) defined by the National Institute of Standards of the U.S. Department of Commerce in FIPS Publication No. 180-1. The message digest is a 160 binary bit number generated by the SHA-1 from any message up to 2^{64} binary bit numbers in length, such as the program instructions stored in the mask program ROM 212 or the ROM (not shown) external to the microcontroller 202. Any changes to the message (i.e., the program instructions of the mask program ROM or the external ROM) will result in the generation of a different message digest. Once generated, the message digest can be stored in the EEPROM 204.

Although the DAA, the DES, and the SHA-1 are preferably employed in the illustrated embodiment, one skilled in the art will recognize that other cryptographic algorithms can alternatively be used

to generate the electronic authentication information and, thus, "algorithm" as used herein shall refer to each of these and their equivalents.

Referring back to FIGs. 2 and 3, once the temporary MAC 238 is generated, the microprocessor 208 stores the temporary ESN 236 and the temporary MAC 238 in the EEPROM 204 as the ESN 205 and the MAC 207, respectively (at block 310). The ESN 205 and the MAC 207 stored in the EEPROM 204 are not encrypted. The microprocessor 208 programs the ESN security bit 230 in the one-time programmable ROM 210 to have a binary "one" value (at block 312). Once the ESN security bit 230 is programmed, the method of programming the electronic information is concluded (at block 304).

Prior to making calls, the local device 104 of FIG. 1 must transmit the ESN 205 of FIG. 2 to the remote device 102 of FIG. 1 for registration on the communication system 100. If registration is not accomplished, no calls can be made or received by the local device 104. Prior to transmitting the ESN 205 to the remote device 102, the apparatus 200 of FIG. 2 authenticates the ESN 205 according to a method illustrated in FIG. 5. Authentication minimizes the opportunity for fraudulent use of the ESN 205 in the local device 104 or other local devices for use in the communication system 100. The method of FIG. 5 is described hereinbelow in conjunction with FIG. 2. The method is embodied in the message authentication program 234 stored in the mask program ROM 212. The message authentication program 234 is executed from the mask program ROM 212 by the microprocessor 208. Control of the execution of the message authentication program 234 is secured by means described in U.S. Patent Application Ser. No. 08/730,188, previously cited.

The method is initiated during a power-up sequence of the local device 104 when the message authentication program 234 receives an ESN authentication command from the microprocessor 208 (at block 500). Upon reception of the command, the message authentication program 234 directs the microprocessor 208 to read the ESN security bit 230 from the one-time programmable ROM 210 (at block 502). If a binary "zero" is read (i.e., the ESN security bit 320 has not been

programmed), the message authentication program 234 halts authentication and flags the microprocessor 208 to prevent registration (at block 504).

If a binary "one" is read in the ESN security bit 230 (i.e., the ESN security bit 230 has been programmed), the message authentication program 234 proceeds to authenticate the ESN 205. The message authentication program 234 directs the microprocessor 208 to retrieve the ESN 205 and the MAC 207 from the EEPROM 204 and store the ESN 205 and the MAC 207 as the temporary ESN 236 and the temporary MAC 238, respectively, in the RAM 214 (at block 506). The message authentication program 234 directs the microprocessor 208 to generate a new MAC from the temporary ESN 236 (at block 508). The new MAC is generated in the manner previously described with respect to FIG. 4 and generation of the temporary MAC 238 during programming. That is, the authentication algorithm 400 generates the new MAC from the temporary ESN 236 and the secret key 232.

Once generated, the message authentication program 234 directs the microprocessor 208 to compare the new MAC with the temporary MAC 238 (at block 510). If the new MAC and the temporary MAC 238 do not match, the message authentication program 234 flags the microprocessor 208 to prevent registration (at block 504). If the new MAC and the temporary MAC 238 are the same, the ESN 205 is authenticated. The message authentication program 234 flags the microprocessor 208 to proceed with registration and transmit the ESN 205 to the remote device 102 (at block 512). Once the microprocessor 208 is flagged to transmit the ESN 205, the method of authenticating the ESN 205 is concluded (at block 504).

Although illustrated in a cellular radiotelephone, programming and authenticating electronic information as described herein will also find application in cordless telephones, two-way radios, trunked radios, pagers, personal digital assistants, and the like, and "device" as used herein shall refer to each of these and their equivalents.

Although the present apparatus and method is shown to secure an ESN in an external memory device, one skilled in the art will recognize that other electronic information, such as program

instructions stored in a ROM external to the microcontroller, could be similarly secured. By associating the program instructions in the ROM with both a security flag contained in the microcontroller and electronic authentication information stored in the ROM and performing authentication on the program instructions during the power-up sequence of the communication device, unauthorized reprogramming and swapping out of the external ROM can be deterred.

Thus, it can be seen that fraudulent use of electronic information to gain access to a communication system, such as a cellular radiotelephone system, can be minimized even if the electronic information, such as an ESN, is stored un-encrypted in a memory device, such as an EEPROM, external to a microcontroller integrated circuit. By employing a one-time programmable security bit in the microcontroller, reprogramming of the ESN is prevented. By employing a random, secret key-based authentication algorithm that creates and requires an association between the ESN and electronic authentication information, such as a MAC, system access can not be achieved by swapping out the EEPROM with another EEPROM containing a different ESN and MAC.

What is claimed is:

Claims

1. An apparatus for securing electronic information in a wireless communication device, the apparatus comprising:

an external memory; and

a microcontroller coupled to the external memory to store the electronic information therein, the microcontroller further comprising a one-time programmable security flag, the one-time programmable security flag indicating storage of the electronic information in the external memory.

2. An apparatus according to claim 1 wherein the microcontroller further comprises a microprocessor, a one-time programmable memory storing the one-time programmable security flag, a mask program memory storing an algorithm to generate electronic authentication information from the electronic information, and an internal bus coupled to the microprocessor, the one-time programmable memory, and the mask program memory, and the microcontroller executing the algorithm to store the electronic authentication information in the external memory.

3. An apparatus for securing electronic information in a wireless communication device, the apparatus comprising:

an external memory to store the electronic information and electronic authentication information associated therewith; and

a microcontroller coupled to the external memory, the microcontroller further comprising an algorithm to generate electronic authentication information from the electronic information, the microcontroller to authenticate the electronic information using the algorithm upon retrieval of the electronic information and the electronic authentication information from the external memory.

4. An apparatus according to claim 3 wherein the microcontroller further comprises a microprocessor, a mask program memory storing the algorithm, a one-time programmable memory storing a security flag, and an internal bus coupled to the microprocessor, the mask program memory, and the one-time programmable memory, and the security flag indicative of storing of the electronic information and the electronic authentication information in the external memory so as to prevent reprogramming of the external memory.

5. An apparatus according to claim 3 wherein the microcontroller further comprises a microprocessor, a mask program memory storing the algorithm, a configuration memory for storing an encryption key for use by the algorithm, and an internal bus coupled to the microprocessor, the mask program memory, and the configuration memory.

6. A method for securing electronic information, the method comprising the steps of:

storing the electronic information in an external memory; and

programming a one-time programmable security flag in a microcontroller to indicate storage of the electronic information in the external memory.

7. A method according to claim 6 further comprising the steps of:

receiving, at the microcontroller, the electronic information from an external programming fixture.

generating electronic authentication information via an algorithm stored in the microcontroller; and

storing the electronic authentication information in the external memory.

8. A method for securing electronic information, the method comprising the steps of:

retrieving electronic authentication information and electronic information from an external memory; and

authenticating, in a microcontroller, the electronic information from the electronic information and the electronic authentication information.

9. A method according to claim 8 wherein said step of authenticating comprises the substeps of:

supplying electronic information to an algorithm stored in the microcontroller;

supplying an encryption key to the algorithm;

receiving new electronic authentication information from the algorithm; and

comparing the new electronic authentication information with the electronic authentication information.

10. A method according to claim 8 further comprising the steps of:

retrieving a security flag contained in a one-time programmable memory of the microcontroller; and

proceeding to said step of retrieving electronic authentication information and electronic information only if the security flag has been programmed.

The Patent Office

Application No:	GB 9723410.8	**Examiner:**	Gareth Griffiths
Claims searched:	1-2 & 6-7	**Date of search:**	16 March 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G4A (AAP), H4L (LDSK, LECC)

Int Cl (Ed.6): G06F 12/14, H04Q 7/32, 7/38

Other: Online Database: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2234611 A	(MOTOROLA) whole document	6 at least
X	WO93/10498 A1	(MICROCHIP TECHNOLOGY) p.31 line 4 - p.34 line 7	6 at least
X	US5432950	(SIBIGTROTH) whole document	6 at least
X	US5379212	(SARNER) col.4 lines 2-22	6 at least
X	US4698750	(WILKIE) whole document	6 at least
X	US4590552	(GUTTAG) col.4 line 51 - col.5 line 22	6 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.